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Algorithmic Modeling of Arts and Other Hard-to-Formalize Subjects

Irina Gorbunova, Sergey Chibirev

Abstract**: *This article is devoted to open questions related to modelling and using of modelling in various areas that hardly can be formalized, such as arts, creativity process, and some hard cases in natural science. We are discussing here the advantage of using modelling and the global question: why we need modelling in such areas and why.***

Several music and scientific centres across the globe are studying the ways of modelling the logical laws of creativity, by exploring generalized parameters of works of art including music. In recent years, Russian scientists have become more interested in modelling the process of musical creativity and music programming. Most frequently, these works are applied in the computer analysis of works of art, to determine the author or the period of creation, to attribute the work of art to a particular school or group.

Fewer papers provide a deeper analysis, including psychological aspects of the perception of art (in particular, music).

The authors have developed a method to construct models in subject areas difficult to formalize, applying it to create a model of musical creativity based on the structural analysis of musical texts, the cyclical structuring of statistical data, and the structural analysis of statistical information. This approach allows creating texts that satisfy the previously obtained or manually provided parameters.

Keywords : mathematical modeling, computer modeling, identification, hard-to-formalize subject areas, music computer technologies.

I. INTRODUCTION

Historically each science passes through several stages beginning from collecting facts through classifications to more active research methods such as experiments and modelling. The good example is biology that started with collecting of herbaria, then the first classification system has been made by Carl Linné, and nowadays the biology (together with genetics, biochemistry etc.) is actually the exact science. But in the most of fields of humanitarian science (and especially in investigations of Arts) the situation is still not far than collecting the artefacts and classification. Some experiments are conducting in sociology and some similar branches, in most of other we are still in Stone Age. Most modern papers represent the stage of classification or search for patterns. To go further, one needs to take the next step. It is modelling that makes it possible to move to the stage of experimenting with creativity models.

It's time to develop methods and instruments for active experiments and modelling of these areas.

A. Literature review

European and American scientists attempt to digitally synthesize, analyse, and transform sounds using music computer technologies (MCTs). Such work is conducted at the University of Hertfordshire, the University of Salford, Access to Music Ltd., and Bedford College in the UK; Institut für Musik und Akustik (Zentrum für Kunst und Medientechnologie) in Germany; CEMAMu (Centre d'Ètudes Mathématiques et Automatiques Musicales) and the Institute for Research and Coordination of Acoustics and Music (IRCAM) at the Pompidou Centre in France; the Centre for Music Experiment at the University of California, the Stanford Centre for Computer Studies of Music and Acoustics (CCRMA), New York University, and the Full Sail University (Florida) in the USA, and others. In recent years, Russian scientists have also become more interested in music programming (Gorbunova & Chibirev, 2019 [12]) and modelling the process of musical creativity (Zaripov, 1971 [42]; Fadeev, 2008 [8]; Filatov-Beckman, 2015 [9]). Another research direction includes practical developments. Here one should mention the work of WIDISOFT, in particular the WIDI Recognition System software, which is designed to identify music and can provide a readable MIDI music score of a music audio file.

In general, today one can talk about two groups of solutions in this area: systems comparing audio prints of a tune and systems that work with the object format of a tune, mostly intended for the general user. These systems are presented either as specialized software or software that can be integrated into the services of mobile operators on various devices. The latter implies the automatic creation of the object format from the others of similar format.

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* Correspondence Author

Irina Gorbunova*, Chief Researcher of the Educational and Methodological Laboratory *Music ComputerTechnologies* of the Herzen State Pedagogical University of Russia, St. Petersburg, Russia. Email: gorbunovaib@herzen.spb.ru

Sergey Chibirev, Research Scientist and Lector at the Educational and Methodical Laboratory *Music Computer Technologies* of the Herzen State Pedagogical University of Russia, St. Petersburg, Russia. Email: ondyon@ ondyon@yandex.ru

There are some other systems (Amin, Reisslein & Shah, 2018 [2]; Blenk, Basta, Johannes, Reisslein & Kellerer, 2016 [3]; Blenk, Basta, Reisslein & Kellerer, 2016 [4]) and some works connected with comprehensive survey and performance evaluation network (Guck, Bemten, Van, Reisslein & Kellerer, 2018 [17]; Guck, Reisslein & Kellerer, 2016 [18]; Guck, Reisslein & Kellerer, 2015 [19]; Li, Veeraraghavan, Reisslein, Manley, Williams, Amer & Leighton, 2012 [23]; Thyagaturu, 2017 [36]; Thyagaturu, Mercian, McGarry, Reisslein & Kellerer, 2016 [37]; Thyagaturu, Dashti. & Reisslein, 2016 [38]).

Some authors propose to use a continuous wavelet transform apparatus as a mathematical tool for generating an amplitude-frequency-time representation of a signal. The continuous wavelet transform apparatus uses standard wavelet functions. The bases of continuous wavelet transform representing the sound of musical instruments allowed the researcher (Fadeev, 2008 [8]) to configure the continuous wavelet transform itself. This made it possible to single out the sound of musical instruments with the same frequency as the base properties and to identify musical objects.

Talking about modelling the process of musical creativity, one should mention the development of systems for automatic creation of accompaniment embedded in most modern digital musical tools, as well as the so-called “composition software”, “auto-arrangers” (such as Band-in-a-Box, etc. with a set of standard music styles). However, we could not find any models with statistical processing for subsequent use in the modelling process.

A new direction in music and the modelling of musical creativity patterns emerged in the second half of the 20th and the beginning of the 21st century due to the rapid development of electronic musical instruments (from the simplest synthesizers to powerful music computers). This new interdisciplinary professional field necessitated the creation and use of specialized music software and hardware and required knowledge and skills both in music and IT, and a complex model of the semantic music space was developed (Gorbunova & Zalivadny, 2018 [15]). This was a firm basis for constructing a model of musical creativity, enabling the analysis and synthesis of musical texts based on the statistical parameters of musical fragments.

When talking about modelling the process of musical creativity, one should mention the development of systems for automatic creation of accompaniment embedded in most modern digital musical tools, as well as the so-called “composition software” and “auto-arrangers” (such as Band-in-a-Box, etc. with a set of standard music styles). However, we could not find any models with statistical processing for subsequent use in the modelling process.

II. PROBLEM STATEMENT

A. Modelling in Science

Historically any branch of science goes through the following stages:

- observation
- collecting of the facts
- facts classifications
- finding logic
- experiments
- modeling

Up to the 18 century the first 4 methods prevails. They are passive, no impact made to the object during research. The last two methods are active and implies the action to the object. Modeling is the newest method, it is also active, but scientist can affect not the original object but the model, having no risks, for example, to break the object. Checking the hypotheses by setting up the experiment on model is the common way of conducting the research nowadays.
All technical and exact science passed such way and currently uses the active experiments and even modeling. Some natural disciplines (such as Biology, for example) also passed this way and starting from collecting facts now became exact

Figure 01. Science stages

science. But in the humanitarian areas and especially in arts we are still in Stone Age just collecting the facts and masterpieces. As I know, there are really few humanitarian areas (sociology for instance) uses some modelling.

B. Hardly formalizable areas

Most of them hardly can be formalizable. Why? There are several reasons prevents us from making formal formula of functioning for these objects.

- We are not able to measure the input and output data (objects are distant or inaccessible)
- We cannot change the input data to conduct experiment (for example, weather forecasts)
- We cannot find any logic between input and output data (probably there is no logic exists?)
- It is not needed or unnecessary to make experiments?

The last reason is very popular for researching of arts, the opinion of huge number of artists is "we need not research it, we wish just enjoy it. Let the creation be the mystery. Scientists, hands off from Mozart! etc." But now it's time to investigate it, we are not in Stone Age.

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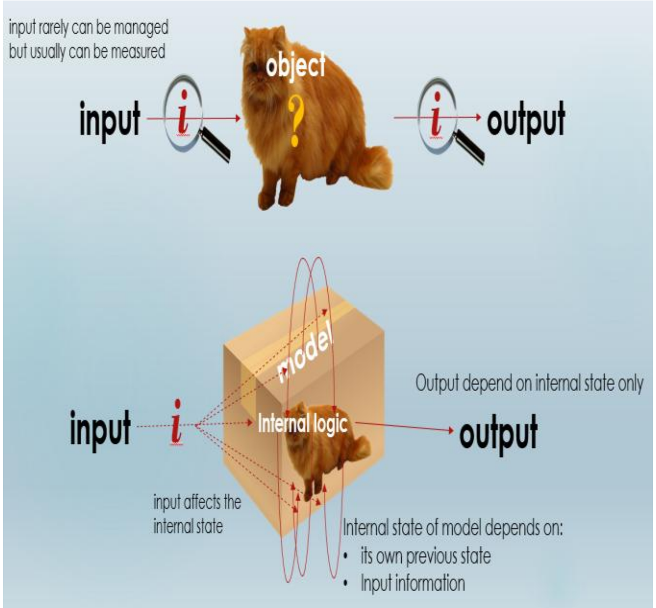

Figure 02. Model is the Black Box

How to build the model in general. We have input and output date and some internal state (data) of the model (assuming that the model is discrete and have the number of states. So, each next internal state depends on previous state and the input data, and the output data depends directly and only from internal state.

C. Information flow in arts

Assuming the object for investigation is some masterpiece of just art object: painting or literature fragment or music, the input flow is some data that author put into the object during the process of creation. So, some information is contained in the art object to be read from it.

We need no create the full model that includes the author and the art object, we need to make just something that produce some output information that requires some unknown criteria (that just need to be investigated yet).

Usually ***in arts*** the output information is not identical to the input one. The main goal of the art is not to store the information exactly but to impress the spectator with this output information. But what is should be? This is the main difficulty in researching of arts.

Really the art object may contain not too much information but has a great impression to spectator. Why?

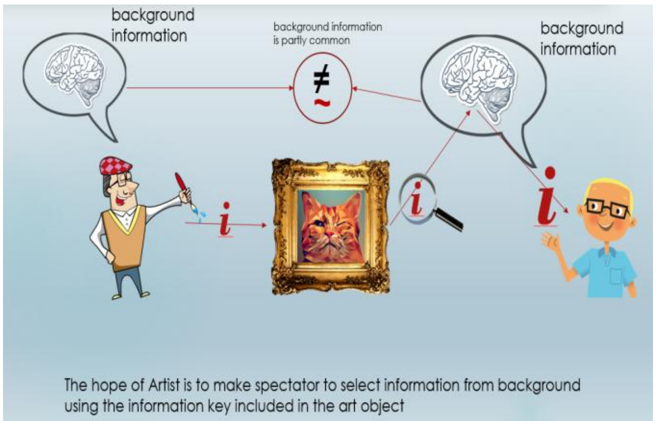

Figure 02. Model is the Black Box

The answer is that there is some other information (and the huge amount) that not contained in the art object but been

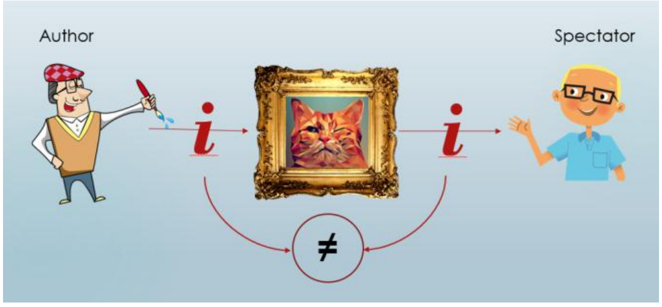

Figure 03. Information Flow in Arts

known to the both author and the spectator. Let us call it background information. Putting only the keys to some information chunks into the art object, author makes the spectator also consume these chunks from common information base. That's how it works.

D. Abstract arts

The different arts contain different amount information in the art objects. More abstract art objects include less information and has less references to the background info.

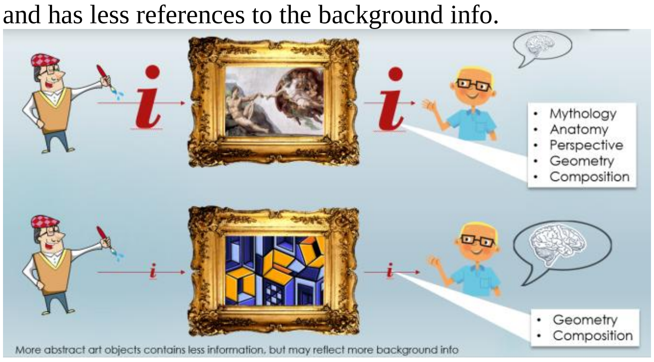

Figure 03. Modelling of most abstract arts

For example, to make the figurative paintings with story from Bible, artist should know at least (in background, and in keys included to the art object):

- mythology, the Bible story and its characters
- anatomy, to paint human figures
- psychology to describe the mood of the scene
- laws of composition to place the figures in the way to maximum impress
- geometry to paint the 3d objects on flat surface
- etc.

It is the significant quantity of information that should be known to the artist, the spectator and keys to it should be included to the art object.

To create the cubistic or primitive genre art object the author and the spectator must know only the law of composition (and maybe some psychology and hints to known objects or some little extra). In this case we have less information included to the object and less background information involved to the process.

More abstract the art object - less information to emulate in model..

E. *Music is the most abstract art for modelling*

Music can be considered as sequence of sounds, each of them has following parameters:

- Instrument timbre (spectral characteristics of the sound)
- Tone
- Duration

Generally, the timbre is the same for all elements (considering solo melody), so we may include to the model only Tone and Duration.

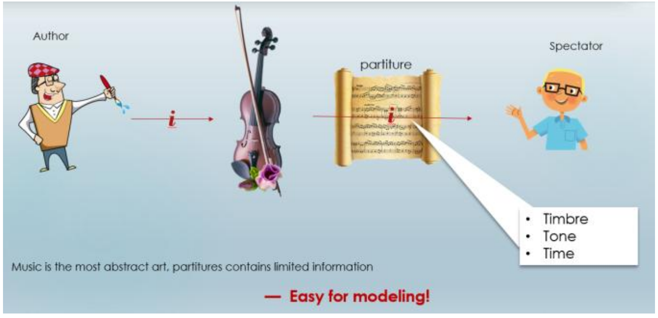

Figure 04. Music is the most abstract art

Since music is the most abstract art, and musical text (as art object) contains less information - it is the easiest area for art modelling.

III. RESEARCH METHODS

The main contribution of our work is the approaches for modelling arts. They are:

- measure
  This is a complicated question for the most of arts, for example how to recognize and measure the elements of paintings. For music it is simple question, we take for analysis the musical text.
- quantization
  Been measured, the data should be categorized and converted to the form, that good for analysis. Input data will be bind to the certain measuring scale. It could be linear or logarithmic or even any custom, the main idea: it should reflect all possible values but without excess. For two close values we must decide: if it is significant for the result - we need to have higher density scale, if no - we can take these values as the same.
- screening
  Other approaches will be discussed in detail below.
- statistics
- finding loops
- finding logic
-

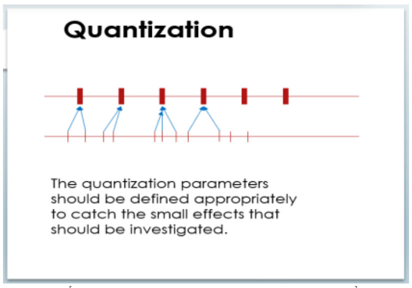

Figure 05. Quantization

Screening

Usually input data is too complicated to find any regularity in it. Screening help to find logic by removing from analysis the dependencies that already found. On the picture: for example, we already found that every second value is significant, so just removing every first value will reveal the hidden regularity.
Considering music:
Taking as input data the frequencies of musical sounds of some music fragment. We see no logic in this stream of values.

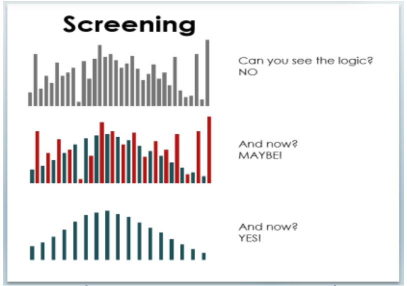

Figure 06. Screening

We noticed that not all the frequencies of input sound are used in music but only ones that can be described with formula

$f = n*2^{(1/12)}$ where n is natural

Formula 01. Quantization of frequency

(This is the frequencies of equal temperament music scale (12-ET). n [1 .. 12] for this scale we have 12 threats in octave)
Then, we will consider as input data the sequence of natural values (n from the formula above). It is easier to fond regularity in it.
We noticed that not all 12 values are used in one music fragment! For any European melody only 7 of 12 values used. (For Asian on blues scales it is usually 5)
After next screening, we will analyze only these 7 values.
Next it is easy to perform statistical analysis of it. All the redundant information is dropped and will not spoil the statistics.
The similar situation with durations: not all the durations are used in music, but only aliquots to each other by formula

$T = T_0 / (2^n)$ where n is natural [1..8]

Formula 02. Quantization of duration

Finding loops

The repeating patterns of data can be found sometimes only after screening.
Using formula above and analyzing the duration as natural values we can found the loop length.
To find the loops we may use several hypotheses. Let us build the regression function to measure the success. Assuming that the length of the loop is some certain value, calculates the result of the function. The best result gives us the right length of the loop.
There are several repeating entities in music: meter, phrase, verse. This periods are typical for song-like structures, but in other music styles there are similar structures that may be formalized in the same way.

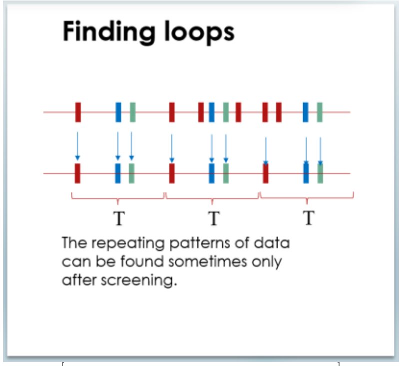

Figure 07. Finding loops

Do it again

It gives the good result to analyze the values got on the previous stage.
Using for analysis the results of previous layer is similar to N-layer Neuron Network.

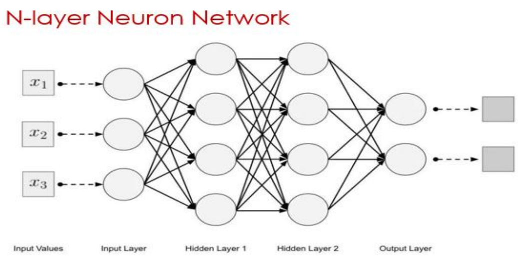

Figure 08. Neuron network

Decomposition of Music

Here is the decomposition of musical data for use in the model.
Using the approaches, described above (written in red on slide), we can decompose the music art object and emulate the process of creation (input data) and consuming (output data).
First, having the sound as input data, exclude from analysis the sound characteristics: timbre and expression, taking for next step of analysis only the music text.

Music text consists of notes, each of them have only two values: tone (frequency) and duration

During the study the following model created:

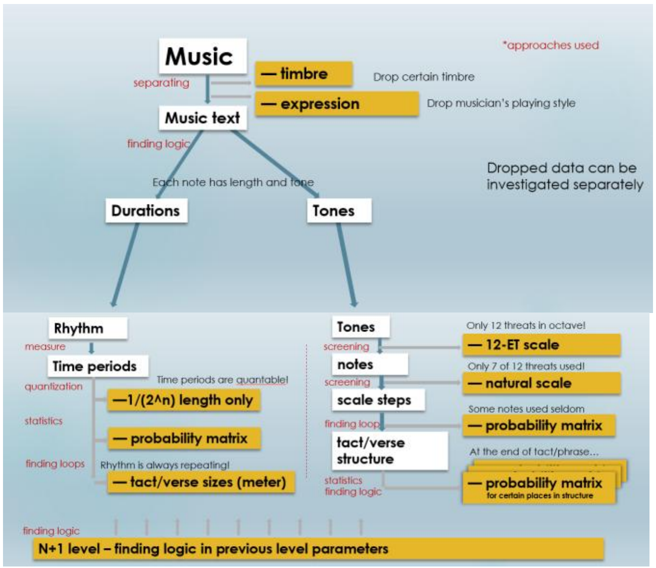

Figure 09. Decomposition of music

The durations make up the rhythm and the tones create the melody – two components of the music.

Durations

As shown above, only $T_0/(2^n)$ durations are used. The T_0 constant defines the tempo. N will be the value for next analysis
We can use statistics analysis to find the probability of certain durations and build probability matrix for future analysis.
Find the periods as shown above. The main period for the music is meter (the size of one tact)
We can use screening and statistics analysis again to find the probability of certain durations ***in certain position*** inside periods (at the beginning, end or middle) and the same for larger periods (beginning/end of phrases, verses etc.)

Tones

As shown above, using screening, move from frequencies to the 12-ET tone (natural number)
And then to the step number in natural scale (7 of 12-ET)
Then using the statistics to build the probability matrix (previous tone -> next tone)
Finding loops (or simply copy the loop value from duration analysis)
Using screening and statistics again to find the probability matrices for certain positions in the periods structure (at the beginning/middle/end of periods: meter, phrase, verses)
Using N+1 approach to analyze matrices, trying to find any logic/regularity in it. It is good idea to conduct the experiment with model, create some music and give it to expert spectators. Try to find dependencies between matrix structure and the expert's perception of music fragment.

For example, the tone matrix with domination of big values above the diagonal means the tendency of ascending sequence in the melody that make its mood "positive" etc.

IV. MUSIC COMPUTER TECHNOLOGIES AS A CREATIVE ENVIRONMENT IN THE SYSTEM OF CONTEMPORARY MUSICAL EDUCATION

The processes of informatization for music education are related to the functioning of a high-tech educational creative environment and the formation of new approaches and fundamentally new teaching methods transform the professional activities of a musician teacher. Innovative musical pedagogy at the present stage is associated with the use of music computer technologies (MCT) - a modern and effective means of improving the quality of teaching musical art at all levels of the educational process. Musicians introducing MCT face such problems in many countries. Scientists and educators note that, despite the effectiveness and accessibility of digital technologies in the educational process (Horita, 2014 [22]), MCT in music education (King, Himonides & Ruthmann, 201 [35]), teachers remain conservative in their approaches to teaching musical disciplines, musical composition (Wise, 2016 [40]); in the real musical educational process, music education programs do not correlate with teaching information technology (IT) (Crawford & Southcott, 2017 [7]); despite the fact that IT is quickly entering all professions, this process is much slower in the music field (Chao-Fernandez R., Roman-Garcia & Chao-Fernandez A., 2017 [5]).

Teachers using MCT in their professional activities note that "it is impossible to resist technical progress and its impact on the younger generation, therefore it is necessary to learn to control and direct this process for the benefit" (Grivault, 2017 [20]); they study the influence of MCT on the development of musical abilities of students (musical improvisation, etc.: Addessi, Anelli & Beghi, 2017 [1]); they use plickers to assess musical skills by scanning real-time student responses using a mobile application using augmented reality technology (Lopez-Garcia, 2016 [26]); offer to discuss their own practical results on the introduction of advanced MCT educational technologies in the compulsory music education system (Serrano, 2017 [32]) and many others.

Musicians note that the use of MCT in the learning process helps to overcome boring, monotonous, routine activities, especially in the initial stages of training (López, 2014 [14]; Goh Khee Meng, 2014 [10];
Trush, 2016 [39]; Sosnevas, 2018 [33]; Hastings, 2014 [21]; Permezel, 2014 [29]; Zhilyaeva, 2014 [43]; Gorbunova & Hiner, 2019 [13]; Nelia Hernández Bean, 2014 [28]; Lourdes García Esperón, 2018 [27]; Córdova Pacheco Gustavo Erasmo, 2014 [6]; Yanpolsky, 2014 [41]; Sushkevich, 2016 [34]; Sargsyan, 2015 [31]; Robert, 2014) [30]).

The experience of understanding the historical, artistic, aesthetic, ideological and methodological foundations of the formation of music computer technologies (MCT), the processes of evolution, the penetration of the MCT into various forms and types of musical, creative and pedagogical activities should be designed as an obligatory component of music computer pedagogical education (Gorbunova, 2019).

A new contemporary educational creative environment is being shaped of the main following components:

● musical computer as a key element of hardware tools and the software for the music computer educational complex;

● methodological tools and its methodological basis, allowing to use the MCT at all stages and in all areas of the musical and educational process (let's emphasize that the MCT require the constant development of new training programs and courses adjusted to modern social needs and corresponding to the development level of these technologies);

● socio-cultural factor of comprehensive human development education.

The lack of scientifically based methodological and psychological analysis of the existing MCT use experience and the prospects of their development in general and vocational music education requires working out the appropriate methods and forms of training. Therefore, the search for effective educational systems taking into account the capabilities of the MCT is promising and reasonable.

The musical activity evolution in terms of both artistic practice and its research development is based on the correlation method of primary and secondary sign systems - material forms of musical and artistic phenomena. We are talking either about recording composer's creative ideas in the standard musical notation (=secondary sign system) or musical text voicing (=primary symbolic system) during performing, or the establishment of the musical art development concept (the correlation of the primary and the secondary sign systems) in the musicologists activities. The digitized music text and sound material could allow to include the electronic technologies in all spheres of musical activity, and apply the system of traditional musical knowledge in the implementation of musicology and musical practice by means of IT.

In 2002 in the Herzen State Pedagogical University of Russia (St. Petersburg) was established the activities of the educational and methodical laboratory "Music Computer Technologies", as a functional structure for the formation of a new professional educational concept. One of the main tasks set for the Laboratory was the development of contemporary educational direction – MCT as an educational and creative environment in general and special music studies, as well as the introduction of IT in the music educational process. Our circle of interests includes the problems of interrelation of natural and technical sciences and humanities, as well as the possibilities of applying the results of such interrelation for the purposes of music education and upbringing. We take part in working out the specialized software for computer music devices and in application of this software in pedagogical processes. We also conduct research in the field of musicology, musical Informatics, computer modeling of processes of musical creativity, timbre programming, art of performing skill and arrangement on electronic musical instruments, creative work in the field of computer music, mathematical methods in musicology, etc. with using MCT.

V. RESULTS

A. Applications of the music model

Our laboratory is working out numerous applications of music models, it is really interesting to conduct various experiments with working model. We have implementations for Windows and Android, applications allow to change parameters while producing the music in real time, so the user have possibility to test the result immediately just listening to the music that is currently playing.

We hope the music modelling will help in researches of other scientists to find out what the music really is, how the process of creation goes and how the various music genres and styles impacts the listener.

Another huge part of applications is the art history, attribution and recovery of lost fragments. Using the decomposition, described above, the model can calculate the matrices of parameters specific for certain composer or even the period of creation and then, running the model, the researcher can get the music that probably could be created by this composer.

Using the model helps in better understanding the music laws and structure, that very useful in studying music disciplines.

And, of course, the model may be helpful for composer. Having the orchestra in the pocket (not only instruments, but also the musicians with their own moods and styles!) gives fantastic opportunities for creating the quality music in very easy way.

Artists may ask "can the model substitute the artist?" No! Human and Computer can create together, helping to each other (Gorbunova & Kameris, 2019 [14]; Gorbunova & Zalivadny, 2019 [16]).

B. Applying the modelling approach

These research methods and approaches of decomposition of data and building the model can be used for most of hard-to-formalize areas such as
paintings and graphics, literature and poetry; any abstract texts and data sequences: weather models, old manuscripts, language of dolphins, signals from outer space etc.

VI. CONCLUSION

We believe that this is the age of science for the Humanities and the arts. From collecting facts (and artifacts), we must move on to active experiments with artistic objects, the process of perception, decomposition, and modeling.

The developed **model** of music creation can help in various fields related to music: music theory and acoustics, psychology and physiology, history and attribution, education and pedagogy, show business and entertainment.

The developed **approach** to decomposition and construction of models of difficult-to-formalize areas can be useful for modeling any data organized in the form of abstract texts: linguistics, any art (literature, poetry, painting, etc.), modeling the globe (climate, planetology, etc.)

REFERENCES

1. Addessi, A.R., Anelli, F., Benghi, D. (2017). Child-Computer Interaction at the Beginner Stage of Music Learning: Effects of Reflexive Interaction on Children's Musical Improvisa-tion. Frontiers in Psychology. DOI: https://doi.org/10.3389/fpsyg.2017.00065
2. Amin, R., Reisslein, M. & Shah, N. (2018). Hybrid SDN Networks: A Survey of Existing Approaches. IEEE Communications Surveys and Tutorials. 20(4): 3259-3306, Fourth Quarter.
3. Blenk, A., Basta, A., Johannes, Z., Reisslein, M. & Kellerer, W. (2016). Control Plane Latency with SDN Network Hypervisors: The Cost of Virtualization, IEEE Transactions on Network and Service Management, 13(3): 366-380.
4. Blenk, A., Basta, A., Reisslein, M. & Kellerer, W. (2016). Survey on Network Virtualization Hypervisors for Software Defined Networking, IEEE Communications Surveys and Tutorials, 18(1): 655-685. First Quarter.
5. Chao-Fernandez, R., Roman-Garcia, S., Chao-Fernandez, A. (2017). Analysis of the use of ICT through music interactive games as an educational strategy. 7th International Conference on Intercultural Education – Education, Health and ICT – From a Transcultural Perspective: Almeria, Spain. Procedia Social and Behavioral Sciences, 237, 576-580.
6. Córdova Pacheco Gustavo Erasmo. (2014, December). El Efecto Mozart Visual e Interac-tiva en los Pianos Casio. Contemporary Musical Education – 2014. Proceedings of the XIV International Research and Practical Conference, ed. Irina B. Gorbunova, St. Petersburg, Russia, pp. 260-262.
7. Crawford, R., Southcott, J. (2017). Curriculum stasis: the disconnect between music and technology in the Australian curriculum. Technology pedagogy and education, 26(3), 347-366.
8. Fadeev, A. S. Identification of musical objects with continuous wavelet transform: Author's abstract of the Dissertation of the Candidate of Technical Sciences, Tomsk, 2008.
9. Filatov-Beckman, S. A. Computer Music Simulation. Moscow: Urait, 2015.
10. Goh Khee Meng. (2014, December). Moving toddlers and parents with MCT in Asia. Contemporary Musical Education – 2014. Proceedings of the XV International Research and Practical Conference, ed. Irina B. Gorbunova, St. Petersburg, Russia, pp. 137-141.
11. Gorbunova I.B. Music Computer Technologies in the Perspective of Digital Humanities, Arts, and Researches. Opcion. 2019. T. 35. № S24, pp. 360-375.
12. Gorbunova, I.B., Chibirev S.V. (2019). Modeling the Process of Musical Creativity in Musical Instrument Digital Interface Format. Opcion. T. 35. № S22, pp. 392-409.
13. Gorbunova I.B., Hiner H. Music Computer Technologies and Interactive Systems of Education in Digital Age School. Series: Advances in Social Science, Education and Humanities Research. Proceedings of the International Conference Communicative Strategies of Information Society (CSIS 2018). February 2019.
14. Gorbunova, I.B. & Kameris, A. (2019). Music Computer Education Concept for Teachers: Raising the Problem. International Journal of Recent Technology and Engineering. T. 8. № 2 S4, pp . 913-918.
15. Gorbunova, I.B., Zalivadny, M.S. (2018). The Integrative Model for the Semantic Space of Music: Perspectives of Unifying Musicology and Musical Education. Music Scholarship, 3, pp. 55–64. DOI: http://dx.doi.org/10.17674/1997-0854.2018.4.055-064
16. Gorbunova I.B., Zalivadny M.S. (2019). Leonhard Euler's Theory of Music: Its Present-Day Significance and Influence on Certain Fields of Musical Thought. Music Scholarship, no. 3 (36), pp. 104-111. DOI: 10.17674/1997-0854.2019.3.104-111
17. Guck, J. W., Bemten, A. Van, Reisslein, M. & Kellerer, W. (2018). Unicast QoS Routing Algorithms for SDN: A Comprehensive Survey and Performance Evaluation", IEEE Communications Surveys and Tutorials, 20(1):388-415. First Quarter DOI 10.1109/COMST.2017.2749760
18. Guck, J. W., Reisslein, M. & Kellerer, W. "Model-Based Control Plane for Fast Routing in Industrial QoS Network", Proc. IEEE Int. Symposium on Quality of Service (IWQoS), 65-66, Portland, OR, June 2015.
19. Guck, J. W., Reisslein, M. & Kellerer, W. "Function Split between Delay-Constrained Routing and Resource Allocation for Centrally Managed QoS in Industrial Networks", IEEE Transactions on Industrial Informatics, 12(6): 2050-2061, December 2016.
20. Grivault-Romanenko L. (2017). Learning to play the piano of bilingual children from two to six years old at the Russian Conservatory Alexander Scriabin in Paris. Materials of the XXV International Conference "The Child in the Modern World. Ecology of childhood". Saint Petersburg, Russia. Pp. 260-262.
21. Hastings K. (2014, December). Anybody Can Play Soft Mozart in the Preschool: Learning to Learn Properly to Develop the Brain. Contemporary Musical Education – 2014. Proceedings of the XIII International Research and Practical Conference, ed. Irina B. Gorbunova, St. Petersburg, Russia, pp. 160-165.
22. Horita, T. (2014). Trend and problems of informatization at school education. Japanese Journal of Music Education Practice, 11(2), 6-13.
23. Li, J., Veeraraghavan, M., Reisslein, M., Manley, M., Williams, R.D., Amer, P. & Leighton, L. "A Less-Is-More Architecture (LIMA) for a Future Internet", In Proc. of IEEE Global Internet Symposium (Infocom Workshop), 55-60, Orlando, FL, March 2012.
24. Lic. Camila Cortina Bello. (2014, December). ¿De donde venimos y hacia donde vamos? Reflexiones y experiencias de vida de una pianista cubana. Contemporary Musical Education – 2014. Proceedings of the XIII International Research and Practical Conference, ed. Irina B. Gorbunova, Saint Petersburg, Russia, pp. 163-167.
25. López, V. (2014, December). 'Soft Way to Mozart' In Spain. From a Conservatory Perspective. Contemporary Musical Education – 2014. Proceedings of the XIII International Research and Practical Conference, ed. Irina B. Gorbunova, St. Petersburg, Russia, pp. 130-132.
26. Lopez-Garcia, N.J. (2016). Evaluation and ITC in primary education: using plickers to evaluate musical skills. Ensayos-revista de la facultad de educacion de Albacete, 31(2), 81-90.
27. Lourdes García Esperón. (2018, December). Reflexiones de una niña "sin oido y desafinada. Contemporary Musical Education – 2018. Proceedings of the XIII International Research and Practical Conference, ed. Irina B. Gorbunova, St. Petersburg, Russia, pp. 125-127.
28. Nelia O. Hernández Bean. (2014, December). Efecto, Modernidad y Creación. Contemporary Musical Education – 2014. Proceedings of the XIII International Research and Practical Conference, ed. Irina B. Gorbunova, St. Petersburg, Russia, pp. 123-125.
29. Permezel T. (2014, December). Dispelling the myth of the exclusivity of musical literacy. Contemporary Musical Education – 2014. Proceedings of the XIII International Research and Practical Conference, ed. Irina B. Gorbunova, St. Petersburg, Russia, pp. 163-167.
30. Robert F. Software as a Basic Music Platform. Proceeding of the 14th Conference. Giuseppe Verdy-Richard Wagner-Moor Emanuel, 22nd February 2014, Szeged, 2014, pp. 119-127.

31. Sargsyan M.E. Experience in the use of computer technology for the development of musical abilities (as an example of an experiment conducted with Armenian students and applicants). Contemporary Musical Education – 2015. Proceedings of the XIV International Research and Practical Conference / edited by I.B. Gorbunova. St. Petersburg: Publishing House of the Herzen State Pedagogical University of Russia, 2015, pp. 132-136.
32. Serrano, R.M. (2017). Technology and compulsory music education in Spain: references for the implementation of good practices. Revista electronica complutense de investigacion en educacion musicalreciem, 14, 153-169.
33. Sosnevas S. (2018, December). Arten der Musikausbildung in Deutschland - Der Blick einer zertifizierten Soft Mozart Klavierlehrerin aus Berlin. Contemporary Musical Education – 2018. Proceedings of the XVII International Research and Practical Conference, ed. Irina B. Gorbunova, St. Petersburg, Russia, pp. 235-238.
34. Sushkevich N.S. Internet technologies in the system of modern music education. Contemporary Musical Education – 2016. Proceedings of the XV International Research and Practical Conference / edited by I.B. Gorbunova. St. Petersburg: Publishing House of the Herzen State Pedagogical University of Russia, 2016, pp. 96-99.
35. The Routledge Companion to Music, Technology, and Education / edited by Andrew King, Evangelos Himonides, S. Alex Ruthmann. New York and London, NY 10017. 2017.
36. Thyagaturu, A. Software Defined Applications in Cellular and Optical Networks. Ph.D. Dissertation Arizona State University, May 2017.
37. Thyagaturu, A., Mercian, A., McGarry, M. P., Reisslein, M. & Kellerer, W. (2016). Software Defined Optical Networks (SDONs): A Comprehensive Survey. IEEE Communications Surveys and Tutorials, 18(4): 2738-2786. Fourth Quarter.
38. Thyagaturu, A., Dashti, Y. & Reisslein, M. SDN-Based Smart Gateways (Sm-GWs) for Multi-Operator Small Cell Network Management. IEEE Transactions on Network and Service Management, 13(4): 740-753, December 2016.
39. Trush I. (2016, December). Soft Mozart in Poland. Contemporary Musical Education – 2016. Proceedings of the XV International Research and Practical Conference, ed. Irina B. Gorbunova, St. Petersburg, Russia, pp. 289-291.
40. Wise, S. (2016). Secondary school teachers' approaches to teaching composition using digital technology. British journal of music education, 33(3), 283-295.
41. Yanpolsky, L. (2014, December). From elementary to concert level: my experience with 'Soft Mozart' program in Israel. Contemporary Musical Education – 2014. Proceedings of the XIII International Research and Practical Conference, ed. Irina B. Gorbunova, St. Petersburg, Russia, pp. 143-145.
42. Zaripov R. H. Cybernetics and music. Moscow: Nauka Publ., 1971.
43. Zhilyaeva N. Classes in music with children of various ages at home as an alternative to a music school in the USA. Contemporary Musical Education – 2014. Proceedings of the XIII International Research and Practical Conference / edited by I.B. Gorbunova. St. Petersburg: Publishing House of the Herzen State Pedagogical University of Russia, 2014, pp. 137-141.

AUTHORS PROFILE

Irina B. Gorbunova was born in Saint Petersburg (Leningrad), Russia. DipMus, Special Music Higher School of the St. Petersburg State Conservatory named after N.A. Rimsky-Korsakov; BSc in Computer Science: Information Technology, Computer Science and Multimedia, Leningrad State University, Ussurisk State Pedagogical University; MA in Education, the Herzen State Pedagogical University of Russia; PhD in Information Technology and Pedagogical Sciences, the Herzen State Pedagogical University of Russia, St. Petersburg, 1989; Doctor degree: Doctor of Pedagogical Sciences and Information Technology, the Herzen State Pedagogical University of Russia, St. Petersburg, 1999. Dr., Full Professor, Chief Researcher of the Educational and Methodological Laboratory *Music Computer Technologies* at the Herzen State Pedagogical University of Russia, St. Petersburg; hold the degree of Honorary Worker of Higher Professional Education of the Russian Federation.

Work experience:

1990 – 2010 - Associate Prof., Professor of the Department of Information Technology of the Herzen State Pedagogical University of Russia, St. Petersburg;

2010 - present - Full University Professor, Department of Information Technology, Institute of Computer Science and Technological Education at the Herzen State Pedagogical University of Russia, St. Petersburg;

2002 – present - Chief Researcher of the Educational and Methodological Laboratory *Music Computer Technologies* of the Herzen State Pedagogical University of Russia, St. Petersburg.

She has more than 300 scientific publications, among them are monographs *Music Computer Technologies: Historical-Theoretical and Practical Aspects*, St. Petersburg: Publ. House "SMIO Press" (2007.) and *Music Computer Technologies: The Problem of Modeling the Process of Musical Creativity*, compiled with participation of S. V. Chibirev, St. Petersburg: Publ. House of the Herzen State Pedagogical University of Russia (2012); textbook *Information Technology in Music*, vol. 1 – 4: vol. 1, *Architectonics of Musical Sound* (2009), vol. 2, *Musical Synthesizers*, 2010; vol. 3, *Musical Computer*, 2011; *Music, Mathematics and Computer Science*, vol. 4, 2013, St. Petersburg: Publ. House of the Herzen State Pedagogical University of Russia.

Prof. Dr. Gorbunova is a Chairperson of the annual Iinternational Research and Practical Conference *Contemporary Musical Education* held since 2002; Chairperson of the annual International Research and Practical Conference *Music Computer Technologies in the System of Contemporary Education* held since 2007.

Dr. Gorbunova is a member of the Jury of national and international competitions of musical creative works, including *Electronic Palette* (Saint-Petersburg), *Music and Electronics* (Moscow), *Music of the XXI Century* (Moscow / Saint-Petersburg), International Festivals and Competitions *Musical Electronics and Multimedia* (Moscow / Saint-Petersburg), *CLARINE of the 21st Century* (Saint-Petersburg), *The World of Art without Borders* (Saint-Petersburg, Russia - Szeged, Hungary), *Bridge of Friendship* (Dortmund, Germany), All-Russian Competition of Electroacoustic Music *DEMO* (Saint-Petersburg).

Prof. Dr. Gorbunova has developed first ever course in Music, called "Music Computer Technologies", which has been offered under the Bachelors of Arts and Sciences (BASc), and she also leads post-graduate course "Music Computer Technologies in Education" available under the MA in Music Education.

Prof. Dr. Gorbunova supervises a number of doctoral and post-doctoral students (more than 30) and lectures on Music Computer Technologies and Information Technology in Music. She supervises research in various directions, among them there are: Theory and History of Culture, Music Art, Information System and Processes, Theory and Methodology of Professional Education, Mathematical Modelling, Numerical Methods and Program Ssystems, Theory and Methods of Education and Upbringing (in Music, Informatics, natural sciences). The research results of Prof. Gorbunova were published in over 300 refereed publications including 49 books and 277 papers in various scientific journals.

Her research activities include such directions as: MCT in professional music education (as a means to expand creative opportunities); MCT in general musical education (as one of the means of education); MCT as a means of rehabilitation of people with disabilities; MCT as the new direction in preparation of specialists of humanitarian and technological profile; MCT in the field of digital arts; MCT in information technology, psychoacoustics and musical acoustics; system of training arrangements and the art of performing skills on electronic musical instruments. Her circle of interests also includes the problems of interrelation of natural and technical sciences and humanities, as well as the possibilities of applying the results of such interrelation for the purposes of music education and upbringing. She also takes part in working out the specialized software for computer music devices and in application of this software in pedagogical processes. Her developments and researches also belong to the field of musical pedagogics and musicology, musical informatics, computer modeling of processes of musical creativity, timbre programming, art of performing skills and arrangement on electronic musical instruments, creative work in the field of computer music, mathematical methods in musicology.

Sergey V. Chibirev was born in 1973, Saint Petersburg (Leningrad), Russia. Education: 1996 - Master of Automatic Control Systems and Information Processing, St. Petersburg (Leningrad) Electrotechnical University; 2007 - PhD in Sciences (Technical Sciences; supervisor - Prof., Dr. of Sc. I.B. Gorbunova).

Work experience: 2002 – present - Research Scientist and Lector at the Educational and Methodical Laboratory Music Computer Technologies of the Herzen State Pedagogical University of Russia, St. Petersburg;

more than 25 years - in IT and computer science; more than 20 years in Web technologies; more than 15 years – lector in Music Computer Technologies; more than 10 years in mobile applications development; team leader and software architect; currently working on mobile application for Android that implements the music creation model.

Main publications: Gorbunova I., Chibirev S. Music Computer Technologies: On the Problem of Modeling the Process of Musical Creativity: monograph. St. Petersburg:

Publishing House of the Herzen State Pedagogical University of Russia, 2012; Gorbunova I., Chibirev S.Computer Modeling of the Process of Musical Creativity.

Proceedings of the Herzen State Pedagogical University of Russia, 2014, no. 168, pp. 84-93; Gorbunova I., Chibirev S., Zalivadny M.S. Music, Mathematics, and Computer Science: Logical, Aesthetic, and Technological

Aspects of Interaction.: monograph. St. Petersburg: Publishing House of the Herzen State Pedagogical University of Russia, 2017; Bazhukova E., Gorbunova I., Chibirev S. Musical Informatics: textbook. St. Petersburg: Herzen University Press, 2020; Gorbunova I.B., Chibirev S.V. Modeling the Process of Musical Creativity in Musical Instrument Digital Interface Format. Opcion. 2019. V. 35. № S22, pp. 392-409.

He has designed the Bachelor’s degree program "Music Computer Technology" and the Master’s degree program "Music Computer Technology in Education" accredited by the Ministry of Education of the Russian Federation. He has designed professional development and retraining programs for music teachers, including “Musical Informatics”, “Information Technology in Music and Musical Education”, etc.

Since 2002, Sergey V. Chibirev has been participating in the annual International Research and Practical Conference Contemporary Musical Education organized by the Educational and Methodical Laboratory *Music Computer Technologies* of the Herzen State Pedagogical University of Russia and the St. Petersburg State Conservatory named after N. A. Rimsky-Korsakov. His articles have been published in various scientific journals and editions.